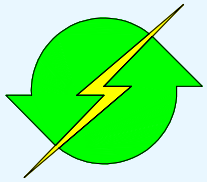

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Recent Operating Experience with the Wales, Alaska, High Penetration Wind-Diesel System

Steve Drouilhet
Sustainable Automation, LLC

Mari Shirazi
National Renewable Energy Laboratory

Wind-Diesel Workshop
Anchorage, September 23-24, 2002

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Wales Wind-Diesel System Overview

- 160 person village
- Avg. load ~ 70 kW
- Installed: Summer 2000
- In partial operation since October 2000
- Fully commissioned March 2002

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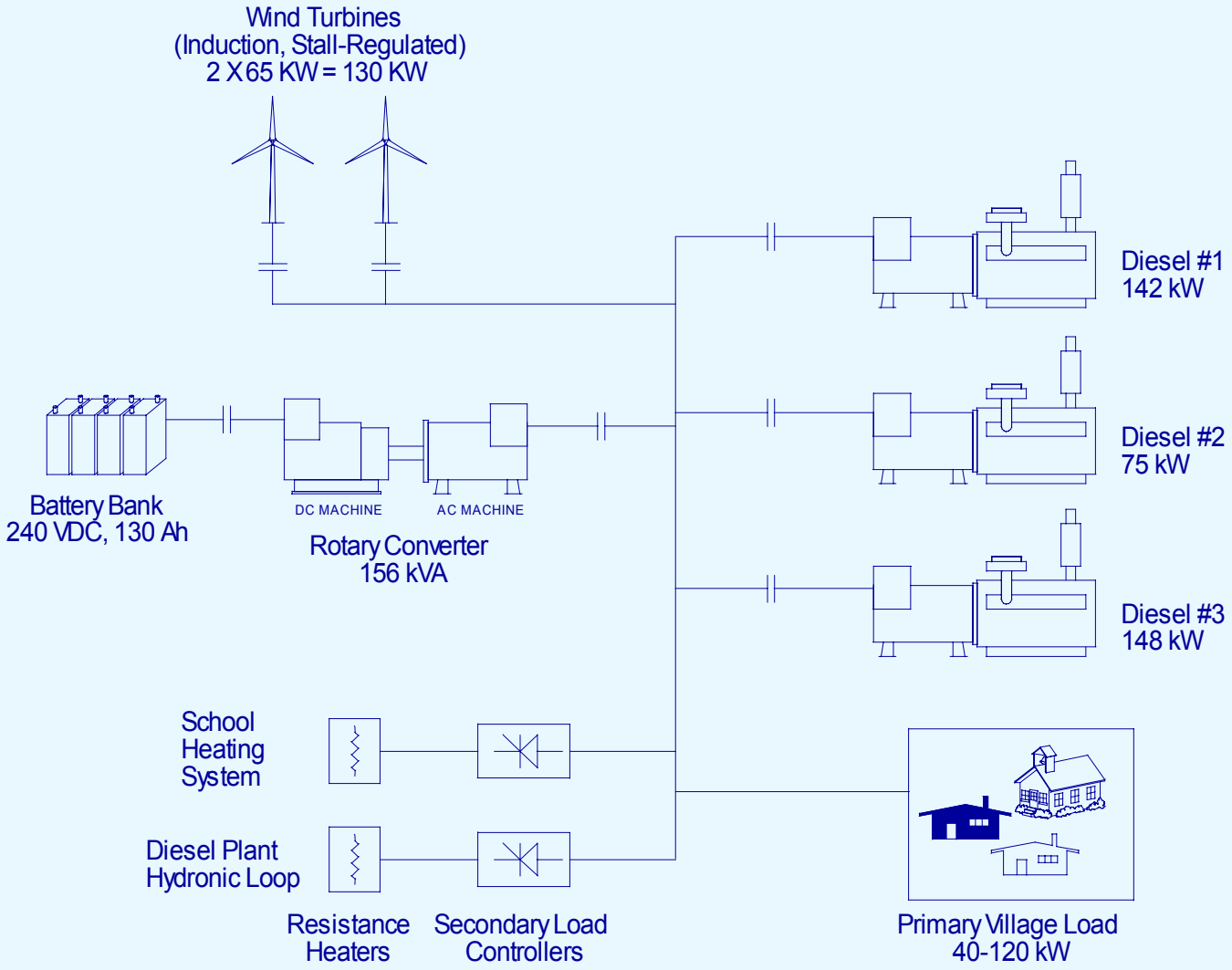
Wales, Alaska
Wind-Diesel System Architecture



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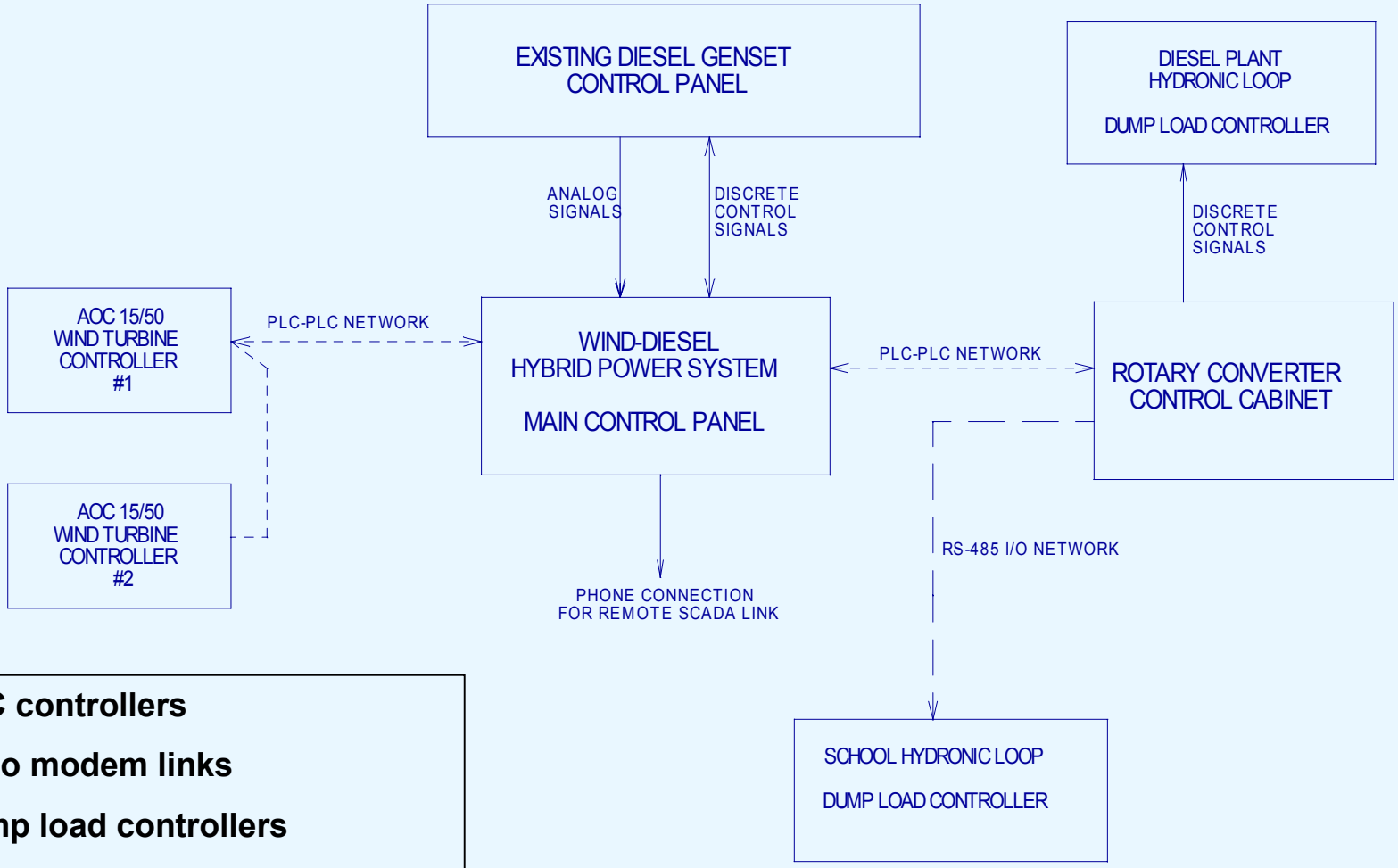
Wales Wind-diesel System Communication And Control



4 PLC controllers

2 radio modem links

2 dump load controllers

1 embedded BASIC computer

Ingoing and outgoing phone links

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Wales System Technical Objectives

- **Demonstrate reliable operation of high penetration system**
  - **Appropriate component dispatch**
  - **Smooth transitions between diesel-on and diesel-off operation.**

- **Fuel Savings**
  - **With 2 turbines, projected wind penetration ~ 70%**
  - **fuel savings ~ 45%**
  - **Projected reduction in diesel run time ~ 25%**

- **Power Quality**
  - **Good voltage regulation**
  - **Good frequency regulation**
  - **No noticeable impact on consumers**

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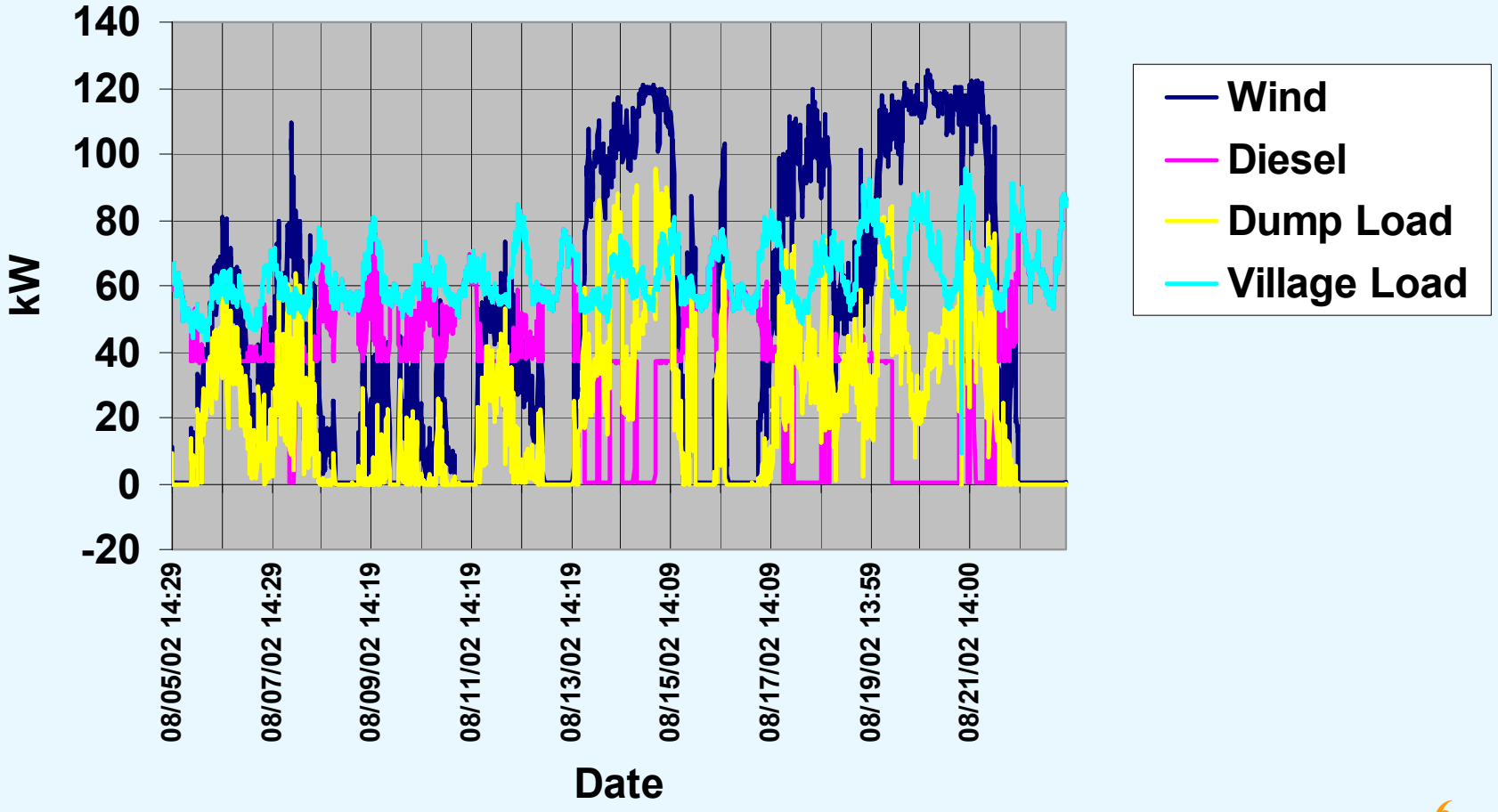
Wales System 10-minute Power Averages
August 5-23, 2002



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Wales Project Energy Flows
August 5-23, 2002

(427 hr. in reporting period)

	kWh	Fraction of primary load
Village Load (Primary Load)	26,950	100%
Diesel Energy Output	15,970	59%
Wind Energy	21,080	78%
Wind Energy to Primary Load	10,980	41%
Wind Energy to Dump Load	9,430	35%
Wind Energy to RC losses	670	2%

		Annual Projection
Diesel Fuel Saved (gallons) (13 kWh/gallon)	845	17,340
Heating Fuel Saved (gallons) (127,000 Btu/gal = 30 kWh/gal)	119	2,440

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Wales Wind Turbine Productivity
August 5-23, 2002

(427 hr. in reporting period)

	Turbine 1	Turbine 2
Average Wind Speed (m/s)	7.1	6.8
Availability	99%	99%
Capacity Factor (rated = 65 kW)	0.382	0.377
Projected annual energy output per turbine (kWh)	216,000	

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Wales Diesel-Off Statistics
August 5-23, 2002

- **Length of reporting period:** **427 hours**
- **Amount of diesel-off time:** **87 hours (20%)**

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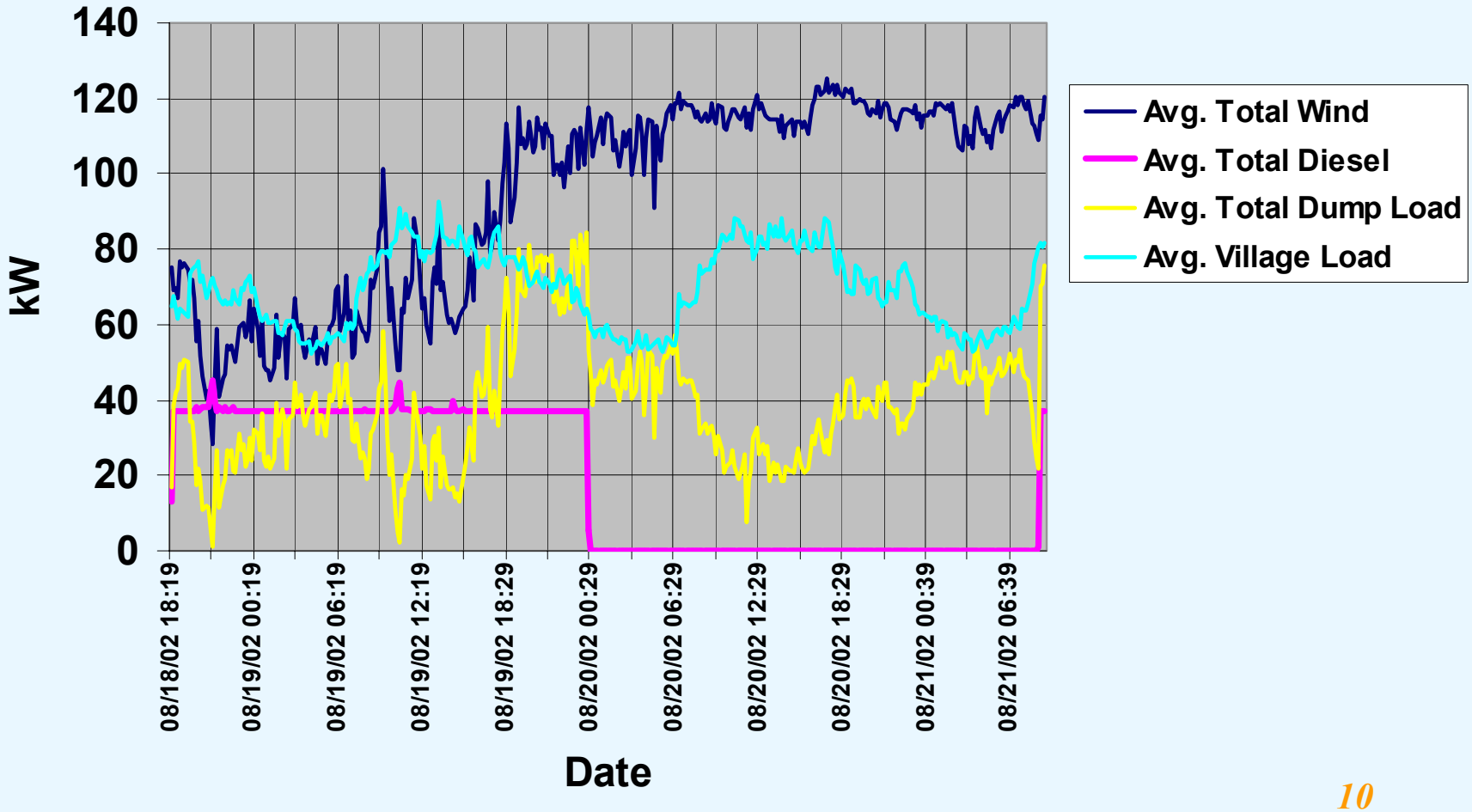
Wales System 10-min Power Averages
August 18-21, 2002



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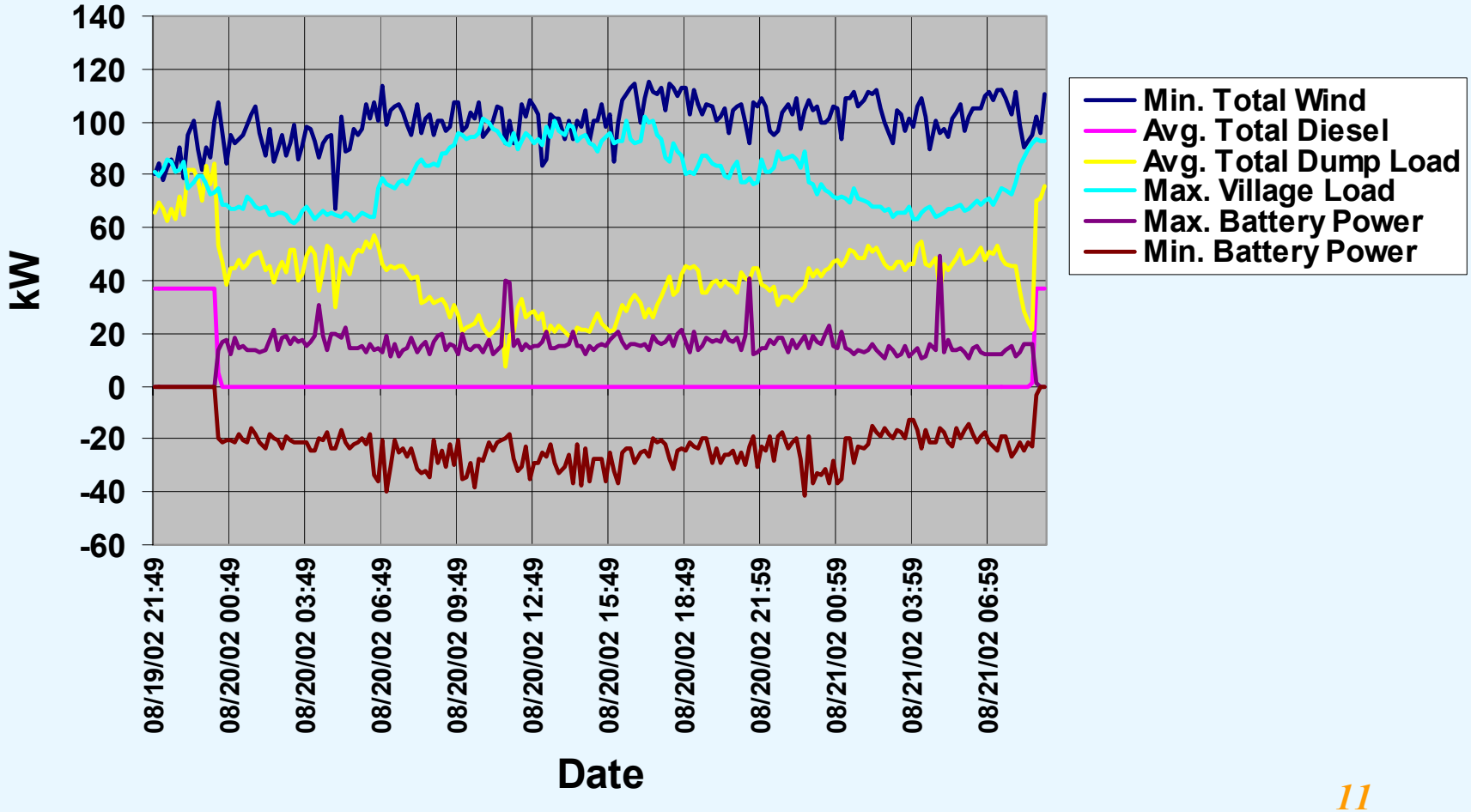
Wales System Power Flows
August 19-21, 2002



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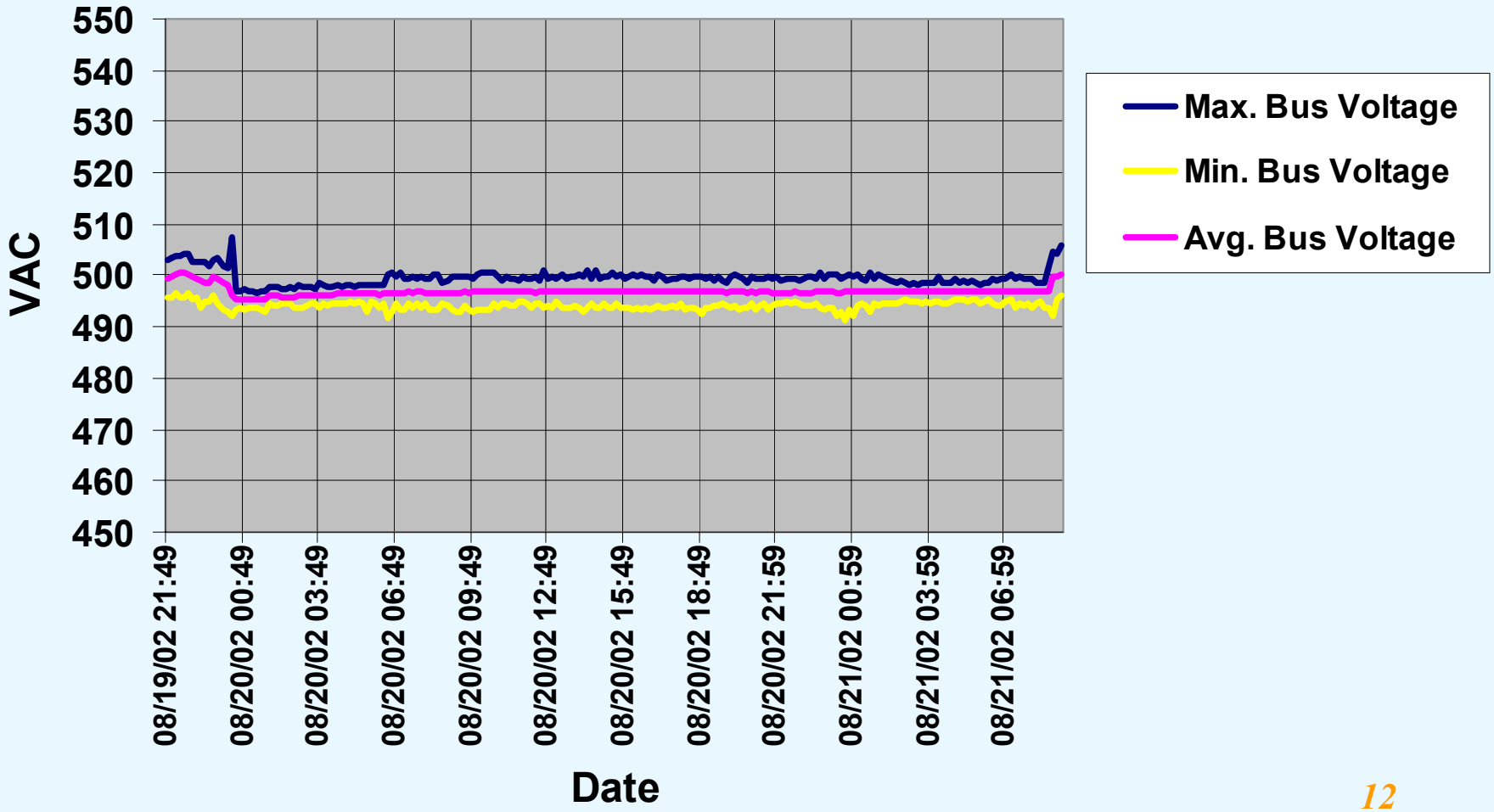
Wales System Bus Voltage
August 19-21, 2002



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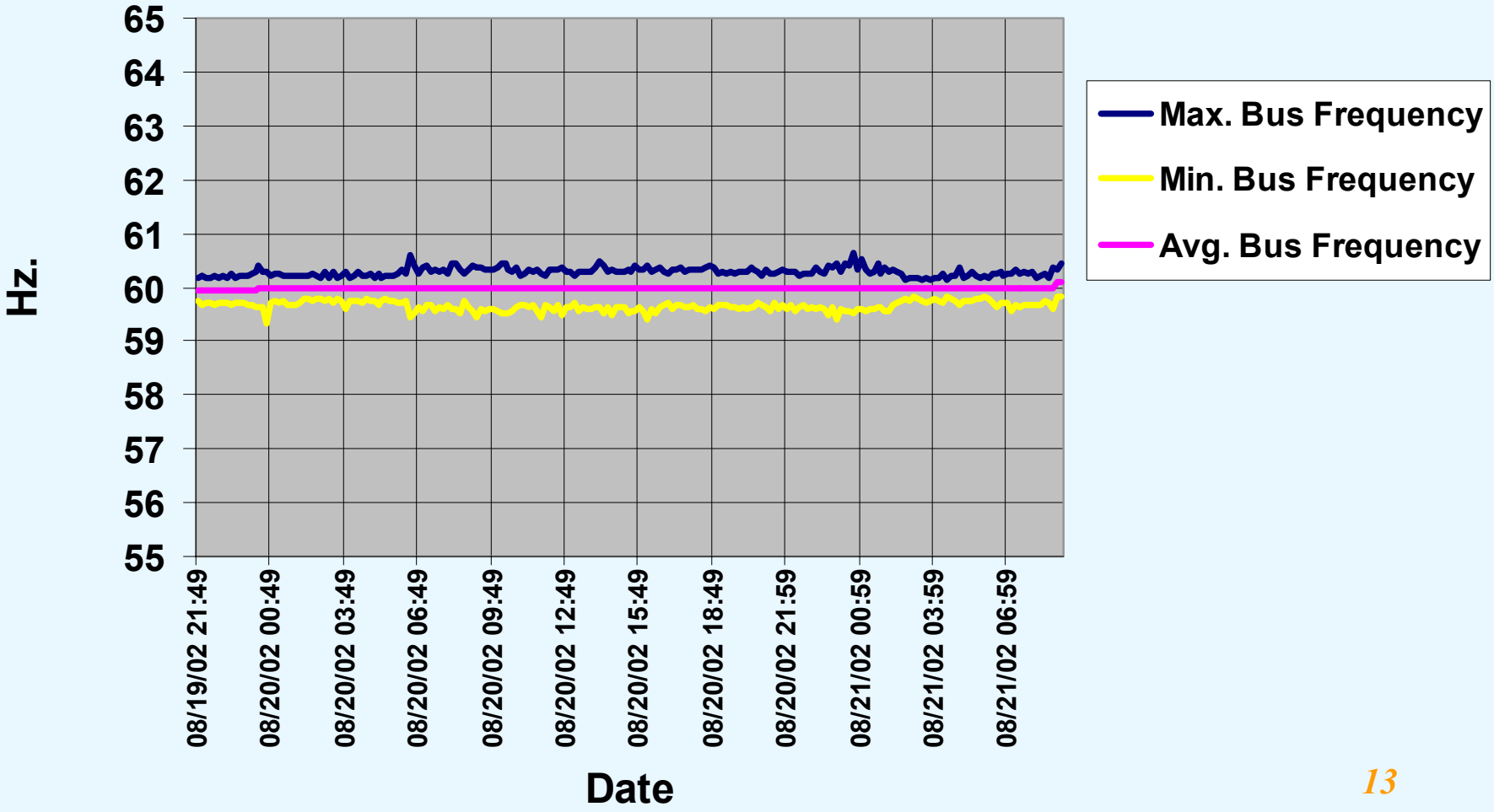
Wales System Bus Frequency
August 19-21, 2002



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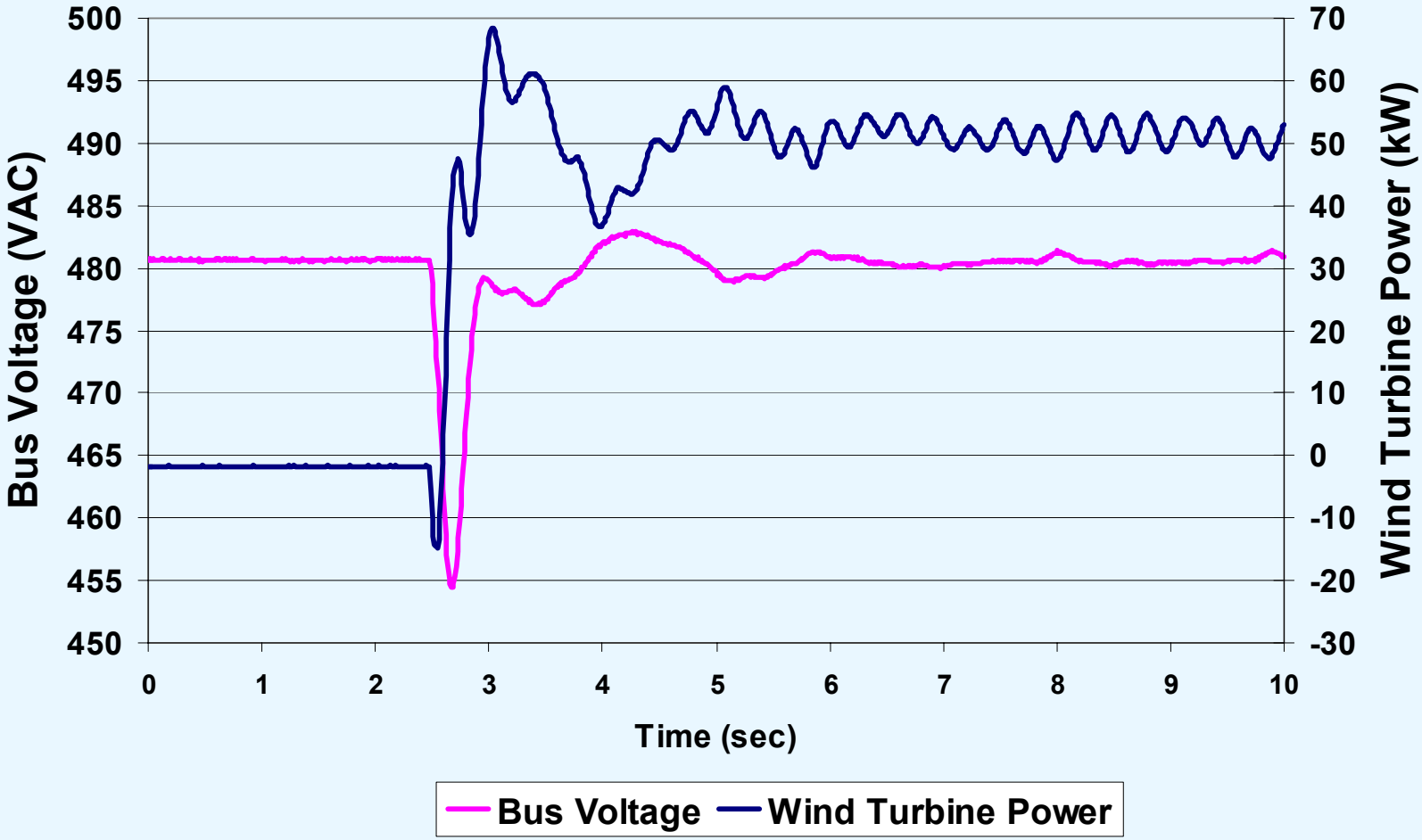
Bus Voltage during Wind Turbine Start
One Diesel Generator On-Line



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Conclusions

- As long as the wind turbines are available and the diesels are capable of automatic operation, the Wales wind-diesel system operates as designed, achieving reductions in fuel consumption and diesel run time similar to original projections.

- The system provides generally satisfactory power quality.
  - Voltage and frequency regulation well within acceptable limits
  - Voltage flicker during turbine starts still a problem
    - Equip wind turbines with soft starts.

- The data acquisition capabilities built into the system controller having been an invaluable tool in assessing system performance and diagnosing problems.